Kokanee Salmon (<u>Oncorhynchus nerka</u>) Population Survey at the Helena Valley Reservoir

A Thesis For Honors Recognition, Submitted to the Department of Biology

By

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Helena, Montana
April 1, 1977

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ACKNOWLEDGEMENTS

We wish to extend special thanks to all who aided us during the study at the Helena Valley Reservoir. We are deeply indebted to Mr. George Holton, for his assistance and guidance on this research topic, for the Fish and Game's allowance of special equiptment, and to Pat Lemon, an assistant in the Fisheries Division of the Montana Fish and Game. Mel Wojcik and Robert Hughes of the Department of Fish and Game for allowing us to participate in the Kokanee plant. Herb Sharp of the Helena Valley Reservoir Project provided valuable information concerning water level of the reservoir.

We extend our appreciation to Dr. James J. Manion, Thesis Director, Mr. Guido M. Bugni, and Mr. Alfred Murray, readers, for their assistance, guidance, and review of this work.

ABSTRACT

Using six surface gill nets, on October 17, 1976, a sample of Kokanee (Oncorhynchus nerka) were taken from the Helena Valley Reservoir, near Helena, Montana. The age and growth characteristics of these fish were studied by the use of otoliths and scales. A comparison with the sampled populations of 1969, 1974, and 1976 was made. An investigation of oxygen content, temperature, turbidity, and conductivity was made to see how much of the lake is suitable Kokanee habitat. Carp (Cyprinus carpio) were also captured, for the first time, during this gill netting procedure.

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INTRODUCTION

Kokanee population at the Helena Valley Reservoir has been under scrutiny by the Montana Fish and Game since 1968. This fish was not originally planted in the reservoir but had made its way there via the pumping network from Canyon Ferry. Early Kokanee populations were of record size, often reaching five pounds. However, we have noticed a decline in the size of the fish caught and the fishing in terms of catch per hour, has fluctuated from excellent to poor.

Our problem and the main objective of the thesis, will be to develop a viable approach in the maintenance of the reservoir. Hopefully one which will again favor the production of a large game fish.

We will approach the problems of decreased Kokanee growth from three directions. First, is their reduced size the result of competition with the white sucker.(Clark-Traynor Thesis). Second, is it the result of heavy plants by the Montana Fish and Game. Thirdly, is it due to the fact that the Helena Valley Reservoir has only marginal Kokanee habitat. Included is an analysis of the condition factors that could affect Kokanee growth.

Throughout our thesis we will be referring to J. Clark and J. Traynor's thesis and K. Frazier's Independant Study. Their research done in 1971 and 1974 respectively, is similar to ours.

DESCRIPTION OF STUDY AREA

Helena Valley Reservoir (Figure 1), a man made reservoir, is located approximately 9 miles northeast of Helena, Montana. The surface elevation varies between 3805 and 3820 feet having a maximum surface area of 518 acres and minumum volume of 10,702 acre-feet. The maximum depth is 70 feet (Clark-Traynor, 1971). On may 7, 1976 we sounded (Sonic Echo Sounder) the reservoir and found the maximum depth to be 60 feet at an elevation of 3818.80 feet.

The Bureau of Reclamation operates a pumping station located at the base of the Canyon Ferry Dam. The water is pumped from a depth of 117 feet through the incurrent canal, a 2.6 mile tunnel connected to a 7 mile canal system, into the Helena Valley Reservoir. Water was pumped into the reservoir from April 12 to October 1 in 1976. The lowest water levels were observed in early April (caused by lack of incoming water and seepage) and early August (caused by height of irrigation withdrawal). A study of water levels was conducted for the years 1972-1976, during the months of April to September (Figure 5).

The Helena Valley Reservoir construction was completed in 1959. The reservoir was filled and its water is used for irrigation and for municipal purposes by the City of Helena. The reservoir's leakage was too severe between 1959 and 1963 for the Montana Fish and Game to establish a fishery. The reservoir was drained in 1964 and

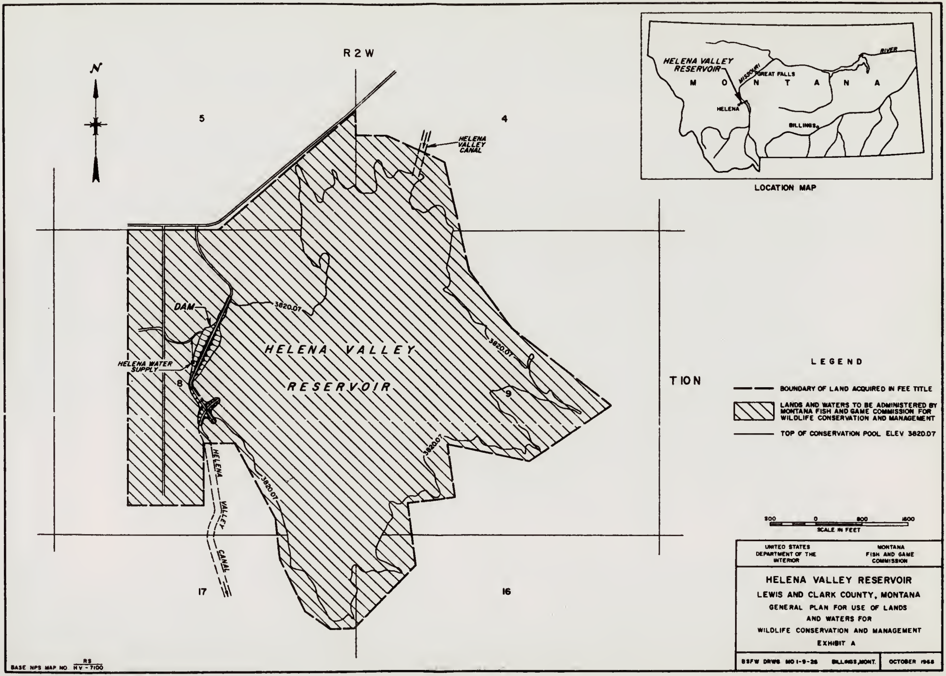

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Figure 1

the leak was repaired.

In 1964, the Montana Fish and Game Department decided to plant smallmouth bass in the reservoir because of the suitable conditions. In 1967, 11,312 smallmouth bass were planted in hope that they would re-establish their population (Art Whitney). Al Wipperman advised George Holton that a friend of his caught a 2-pound smallmouth bass on March 23, 1976. Prior to this the last known smallmouth bass were caught in mid-June 1975 by Erv Kent (14") and by Vince Yannone (6"). The reservoir did not provide the necessary habitat for a smallmouth bass population to establish itself.

Although the white sucker population is the most prevalent, the Kokanee have been the most important fishery. The Kokanee fishery developed initally without management from the Montana Fish and Game. Kokanee were established in the reservoir through migration from Canyon Ferry during water pumping procedures (Clark-Traynor, 1971). We observed the following fish species during our study: Kokanee (Oncorhynchus nerka), yellow perch (Perca flavescens), white sucker (Catostomus commersoni), and carp (Cyprinus carpio). In addition to these species, Clark and Traynor (1971) reported the following species from Helena Valley Reservoir (HVR): brown trout (Salmo trutta), longnose sucker (Catostomus catostomus), rainbow trout (Salmo gairdneri), mountain whitefish (Prosopium williamsoni),

smallmouth bass (<u>Micropeterus dolomieui</u>), flathead chub (<u>Hybopsis gracilis</u>), burbot (<u>Lota lota</u>), and mottled sculpin (<u>Cottus bairdi</u>).

CONDITION FACTORS OF THE LAKE

Purpose and Method of Water Temperature Analysis

The main objective in obtaining temperature calculations is concerned with determining the water stratification in regard to temperature values, or the limnology of the lake. Every spring Helena Valley Reservoir (HVR) experiences an overturn of its water strata (Welch 1935), in which the ice melts, followed by the sinking of the warm surface water, which forces the colder subsurface water strata upwards. Spring winds aid in this interaction until the lake becomes homothermis. In May the reservoir will begin to develop a peculiar phenomenon, that should continue throughout the summer months of June, July and August. An epilimnion, or zone of summer circulation (Welch, 1932) will develop near the surface, followed by the thermocline, an area which experiences a sharp drop in temperature per unit depth. Below the thermocline, the water body is nearly uniform in temperature and is recognized as the hypolimnion. It is apparent that seasonal and climatical factors participate in the variety of reservoir situations. However, the calculations and relations of such phenomenon would require more arduous participation and time then we could devote.

Two types of thermometers were used to obtain temperature data at HVR. On May 7 and June 20, the Maximum-Minimum was used. The instrument consist essentially of a U-shaped tube, with a slender, elongated reservoir at the upper

end of the left arm and a pear-shaped reservoir at the upper end of the right arm. Part of the capillary tubing is filled with a liquid (creosote). An index (glass enclosed iron wire) is in each limb of the tubing. After setting the index's in each column, the thermometer is lowered into the water. Creosote in the left-hand bulb contracts as the result of going into colder, deeper water and the mercury rises in the left hand limb pushing the index up the tube to the minimum reading (Welch 1948). On July 29 and October 18-19, we used the Model T-4 Marine Hydrographic Thermometer. The marine thermometer proved to be a more convenient instrument and one less susceptable to calculation discrepancies. However, the information gained from both instruments proved conducive to our theory concerning the Kokanee habitat.

Interpretation of Temperature Analysis Data

On May 7, we recorded the maximum depth of the area researched to be 60 feet. This was the maximum depth and would be subject to severe fluctuations due to the irrigation requirement of this area. As can be seen in reference to Table 1, the lake underwent spring overturn, whereby a homothermis water condition was reached and stratification began.

On June 20, temperature conditions were nearly homothermic, which we found unusual for this time of year. However, it must be pointed out that the weather was stormy

Table 1

Temperature Analysis of Helena Valley Reservoir

Date	Area	Temperature	Time of Day
May 7, 1976[a]	Surface	55°F	10:40 a.m.
	Bottom (40')	45°F	"
	Midway (21')	46°F	"
	(12')	50°F	"
	Surface	56°F	3:00 p.m.
June 20, 1976[a]	Surface	60°F	1:45 p.m.
	Bottom (39')	58°F	"
	(24')	59°F	"
July 29, 1976[b]	Surface	68.9°F	6:30 p.m.
	(9.8')	62.6°F	"
	(19.7')	59.0°F	"
	(29.5')	57.8°F	"
July 29, 1976[b]	Surface	68.0°F	7:25 p.m.
	(19.7')	58.1°F	"
	(29.5')	57.2°F	"
	(39.4')	56.3°F	"
October 13, 1976[b]	Surface	50.0°F	5:30 p.m.
	(5')	50.0°F	"
October 18, 1976[b]	Surface	47.5°F	9:05 a.m.
	(33')	47.5°F	"

[a]Maximum-Minimum Thermometer used

[b]Hydrolab T-4 Marine Thermometer used

at this time, with high winds and rain. We are now entering temperature conditions which present a significant limiting condition. Surface temperatures have increased 5°F, which is nearly congruent with that of the subsurface waters. Maximum depth recorded was 39 feet at a temperature of 58°F, which will be pointed out to be the maximum range of prime temperature conditions for Kokanee habitat (Refer to Table 1).

Mid-summer posed the most severe hazards to a healthy Kokanee fish population in the HVR. Though increased radiation raised the average temperature in each of the strata, the reservoir was subject to severe water level fluctuation (Refer to Figure 5). As a result, the area that would be conducive Kokanee habitat is greatly reduced. Decreased Kokanee habitat together with increased water temperatures would present a detrimental condition for this species.

The level of temperature most preferred by the Kokanee species lay in the 53.6° to 57.2°F stratum (Brett, 1952). Increase in the stratum temperature above the preferred range results in lowered growth rate, increased susceptability to disease, and/or death. Fingerlings, fish measuring 2-inches or less, juveniles, and young adults appear to be the most affected by the situation. Mature adults may tolerate temperatures up to 80°F, however mortality greatly increases in this range.

With reference to Table 1, the temperature at the

surface would most likely prevent infiltration by young Kokanee salmon. The presence of an epilimnion does not seem prevalent enough to show a noticeable temperature per depth variance on this date (July 29). It appears as if the thermocline ranges from just below the reservoir's surface to a depth of 9.8 feet (68.9°-62.6°F): the hypolimnion thus follows at a mean depth of 9.8 feet to the reservoirs bottom. These results are consistant in each of the two tests, though over the course of the critical summer months, the depth of these strata may vary. Since the thermocline area has a temperature range that would not be favorable to the Kokanee, the main body of Kokanee would be present at depths greater than 9.8 feet, or below the thermocline.

Temperatures for the period in which the fish were netted at HVR, on October 18, are listed in Table 1. The reservoir cooled significantly along with obtaining a more homothermous condition. Pumping from Canyon Ferry terminated, resulting in a permanent water supply that would not be subjected to withdrawal until the following irrigation season (Clark-Traynor,1971). Temperature consideration as a primary limiting growth factor of the Kokanee population will be discussed later in this paper.

Purpose and Method of Dissolved Oxygen Analysis

Oxygen is an important element necessary in the survival of the Kokanee species, and one which must be supplied continually in sufficient concentration. We wanted to determine if the cause of latent growth in the Kokanee population was do to a deficient oxygen concentration in the HVR. Measurement was conducted by collecting a small sample of reservoir water, and utilizing the Alsterberg (Azide) Modification of the standard Winkler Method. To the water solution dry posder chemicals (in plastic pillows), such as alkaline iodid-azide, manganous sulfate, and sulfuric acid were added. This system used the "Drop Count" titration principle, through five steps in just several minutes (The American City, 1968).

Interpretation of Dissolved Oxygen Concentration

Notice with reference to Table 2, that the surface oxygen concentration and that of the bottom reservoir strata on May 7 are nearly identical. This phenomenon is another indication of the spring overturn which occurs

Table 2 Dissolved Oxygen concentration analysis at HVR.

Date	Area	Titration*	Time of Day
May 7, 1976	Surface	12 Drops	11:00 a.m.
	Surface	13 "	1:30 p.m.
	Bottom (49')	12 "	"
July 29, 1976	Surface	12 "	6:30 p.m.
	Bottom (40')	3 "	"

*One drop = one part of oxygen per million parts of water.

in most bodies of water. Surface water is turned under as the winds drive the water against the shallow shore line areas. This condition would not pose a situation that would limit propagation and growth of the Kokanee species. However, we noticed a significant decline in the subsurface oxygen concentration on July 29 (Refer to Table 2). As we would expect the surface waters showed no discrepancy from the normal oxygen concentration, but the bottom oxygen concentration diminished by 9 ppm. with respect to surface water. Whether the lower oxygen concentration at this depth prevaded to harm or limit the Kokanee distribution and activity, we could not assimilate. In relation to the minimum oxygen requirements of the Kokanee, we could not find relevant information concerning this, such as research conducted in other areas of fish habitat.

The following conclusions concerning oxygen requirements were reached. First, since the food consumption rate is not only a function of food availability but also of feeding activity, therefore activity as well as appetite can be depressed by a reduction of dissolved oxygen (Doudoroff-Shumway, 1966). Second, concentrations below 2 mg/liter together with average summer temperatures can not be tolerated for long periods by most fish (Doudoroff, 1957). Third, abnormally high concentrations of oxygen may also have deleterious effects, in fact the literature cited indicates that high oxygen concentration may be more of a limiting factor of growth than a low oxygen concentration. We can

be sure that the levels of dissolved oxygen vary with respect to seasonal and environmental factors. However under what circumstances the growth rates of fish in their natural environment depend on the oxygen supply, we do not know.

Purpose and Methods of Suspended Solids Analysis

This approach was made in order to determine if the accumulation and suspension of various elements could limit the growth of the Kokanee in the HVR. Two methods of analysis were used to collect the essential data. The Myron L "DS" Meter, Model EP (Myron Co., 1972) was used to measure the conductivity of the water with respect to the amount of dissolved solids. This instrument is a self contained unit which automatically corrected to 25°C for changes in solution temperature from 32°F to 120°F (Refer to Table 3). It's reasonable to assume that the specific

Table 3 Suspended analysis (conductivity) at HVR.

Day	Area	Conductivity*	Time of Day
July 29, 1976	Surface	2.5	6:45 p.m.
	Midway (22')	2.6	"
	Bottom (40')	3.0	"
October 18, 1976	Surface	2.6	4:30 p.m.

* Measured at 100 sensitivity, in micromhow/cm^3.

conductance would vary from the surface through to the reservoir bottom, due to subsurface water currents and the precipitation of higher water particles.

Secchi disk analysis was also conducted to measure the ability of light penetration into the water. The Secchi disk measured 20 cm. in diameter and was divided into 4 alternating black and white quadrants. A fixed line was attached to the center of the disk (Welch 1948). By lowering the disk into the water and noting the depth of its disappearance, then raising it and again noting the depth of its reappearance, the average of this measurement would be considered to be the limit of visability with respect to significant light penetration.

Interpretation of the Results

We were unable to relate the data collected with previous research, which therefore inhibited our ability to formulate a conclusive theory as to the lake's present condition; one that would limit Kokanee growth. On July 29, the limit of visability (Secchi Disk) was calculated at 6.4 feet. Large blue green algae blooms, that of Apanizomenon flosaque and Polycystis aeruginosa (Wright, 1956), and floating weed beds dominated the surface littoral region of the lake. Though the algae expressed its characteristic greenish features throughout the lake. Vast algae blooms, also that of Apanizomenon (personal communication, George Holton), dominated the area on October 18-19 which indicates that the HVR offers satisfactory propogative conditions for this species. Turbidity not only is caused by large algae blooms, but also from plankton and other zoological species which prevail in the HVR. In addition

to these organic populations, inorganic suspensoids such as clay and soil particles could precipitate in these waters. Though the effect of increased turbidity would be less obvious, it has the potential to reduce the photosynthetic zone in the lake and thereby lowering its overall productivity (Lagler, 1952). To determine the extent of the turbidity conditions in the HVR on the Kokanee population, would consume more time than we could devote. Perhaps this situation is a primary factor in the residual growth of the Kokanee, however a persistent approach with the availability of acute scientific knowledge would offer better judgement then either of us could approximate.

AGE AND GROWTH

Relative Size History of Kokanee in HVR.

After induction of water, via the pumping and canal system from Canyon Ferry, Kokanee were observed in the Helena Valley Reservoir. It could therefore be presumed that the Kokanee adopted the HVR as a fishery habitat by chance rather than purposely. Fisherman reported to Fish and Game officials (Notes to File, Department of Fish and Game) of Kokanee catches ranging from 6-inch to 22-inch, or near 5 1/4 pounds (2382 grams). Records concerning this data have been on file at the Department of Fish and Game in Helena, from mid-July 1968 to the present day.

Because of the popularity of this sporting fish, HVR has gained a reputation of producing record size Kokanee, and thus has attracted intra-state as well as inter-state anglers. The record weight for Kokanee in the United States and Canada was 1814 grams (4 pounds) until erased by the 5 1/4 pound catch, at the HVR. Gill netting records of the Montana Department of Fish and Game show on June 25, 1968 a Kokanee weighing 2087 grams was captured (George Holton, personal communication). A Kokanee weighing 1865 grams was observed in a creel census in October, 1969. Kokanee near or beyond record size have not been tabulated at HVR since, though this is not to say that such do not exist.

Kokanee are angled with a variety of devices available

to the average fisherman: Thomas Lures, Mepps Spinners (red and white with silver back), Dare Devils (pounded brass, red, and white), maggots, nymph and muskrat wet flies, copper "Kokanee King" with a fluorescent red or orange head, worms, fresh water shrimp, corn, and other personal combinations.

<u>Collection at Helena Valley Reservoir-October, 1976</u>

In order to judge the length-weight frequency and the age-scale criteria, we endeavored to collect raw data through netting procedures. Six (6) floating gill nets were placed on the HVR, October 18 at 5:00 p.m. (Clear-45°F). Nets were suspended by buoys along its length and secured to the lake bottom by lead anchors, attached to netting by guide ropes. Location of the netting varied from 35 to 80 yards, south by southeast off the reservoir dam. Net #1 was of the monofilament strand with a graduated mesh size of 1-inch to 2-inch, and an overall length of 30.5 meters (100 feet). Nets #2-6 were composed of nylon material with a graduated mesh size ranging from 3/4-inch to 2-inches, and an overall length of 38.1 meters (125 feet). Refer to Table 4.

Al Wipperman, Joe Nevela (associated with the Montana Department of Fish and Game). George Holton (assistant Fisheries Division Administrator, Montana Department of Fish and Game) aided us in the setting of these nets. At 9 a.m. October 19, (Clear-40°F) the nets were removed from the

lake to the shore where they were analyzed individually.

Table 4 Net Characteristics, HVR, October 18-19, 1976

Net Number	I	II	III	IV	V	VI
Type	Monofil.	Nylon	Nylon	Nylon	Nylon	Nylon
Length of net	30.5 m	38.5 m	-	-	-	-
Mesh Size	1"-2"	3/4"-1"	3/4"-2"	-	-	-

Denetting was done manually for all nets, which included removal of Kokanee (Oncorhynchus nerka), white sucker (Catostomus commersoni), and yellow perch (Perca flavescens). Considering that the placement of the nets on the reservoir was random, the catch per net would likewise be so. Kokanee represented 72.70% of the total catch, white sucker 31.29%, and carp .71%; the Kokanee ratio is better than 2:1. Also included in the catch were the distinguishable mature Kokanee which represented 17.80% to the total Kokanee catch (Refer to Table 5).

Age analysis of the general Kokanee population was to be deducted from the Kokanee which were netted. For the immature fish, or 82.2% of total Kokanee caught, scales were removed with a knife, from the side of the body just above the lateral line and below the origin of the dorsal fin. Scales were stored in scale envelopes, with the length-weight measurement recorded. Scales, like other bony structures, disclose seasonal changes in rate of growth; particularly true in waters which become

Table 5

Breakdown of Fish Caught in HVR, October 18, 1976

Net No.	I	II	III	IV	V	VI
No. of Kok. Caught	39	21	63	46	71	69
No. of Mature Male Kok. Caught	8	4	2	3	5	4
No. of Mature Female Kok. Caught	9	2	2	7	3	6
No. of Total Mature Kok. Caught	17	6	4	10	8	10
No. of Sucker[a] Caught	26	30	13	33	19	12
No. of Other[b] Species Caught	0	0	0	3	0	0
Total per net of Kok, Sucker, Carp	65	51	76	82	90	81

[a]White sucker is species tabulated.

[b]Carp species tabulated.

cold enough to interrupt growth for part of the year (lagler, 1952). Mature Kokanee, because of the regression of their scales necessitate bone analysis to determine age, of which the otolyths (ear stones) are most economically reliable. We cut the skull, several millimeters dorsally and behind the eyes, and removed the sacculus which contained the otolyths. Storage and data recorded was identical to scale recording. Determining the age by the otolyth method required distinguishing the variability of the translucent zones. A translucent zone is layed down every year and each zone is separated by an opaque zone. For example, yearling (I+) have two translucent zones with an intervening opaque zone.

Results of Otolyth and Scale Analysis

Three-hundred and nine (309) Kokanee, one-hundred and thirty-three (133) suckers, and three carp were netted. Mature females (29) represented 6.82% of the total count (425), while mature males (26) registered at 6.11%, which indicates an even distribution among the sex's. Netting of the carp species, though representing only .7% of the total fish count, presents a new force to contend with in regards to the Kokanee population. Its possible future effects will be delt with in the preceeding discussion.

The sucker catch averaging 11.78 inches (302mm) and 31.3% of the total catch did not show a related frequency

with respect to percentage of total catch in past years. Data collected in October 1974 (George Holton, Montana Fish and Game) showed white sucker averaging only .95% of the total catch, while the white sucker count in July of 1974 averaged 91.3% of the total fish count. Variability with respect to time of year, location of set, total number of nets sets, and climatic factors contribute to the diversity of the information. The white sucker population and its role in the HVR fishery will be interpretated in full later in this discussion.

Discussion

Kokanee Species (Oncorhynchus nerka)

The dorsal surface of head and body range in color from brilliant steel-blue to green-blue while sides over all are bright silver with no distinct markings; ventral surface is white to silver (Scott-Crossman, 1973). Mature males and females turn bright red to dirty red-grey along with deformities of head, snout, mouth, teeth, a small hump before the dorsal fin, and embedded scales. Mature males can be distinguished from females almost immediately by a prolonged, hooked, turned up snout and gaping mouth. Failure of adequate spawning facilities at HVR prohibit Kokanee spawning which would normally occur in the fall. Growth is rapid but also extremely variable as noted in northern British Columbia, where maturity is reached at 8-9 inches (203-229mm), while at HVR mature fish varied from 15- 17.9 inches (348-458mm) in 1976. Generally, Kokanee mature, spawn, and die at 4 years of age, but fish age 2-4 years may mature and fish as old as 8 years have been seen. Kokanee, which in spring and fall may inhabit all depths, usually inhabit the upper middle layers of the open lake during the summer. With increased summer temperatures and during winter conditions, Kokanee move into deeper water (Scott-Crossman, 1973). In the summer, they have extensive daily vertical and onshore-offshore movements, possibly associated with temperature

and food (Scott-Crossman, 1973).

The Kokanee is mainly a pelagic, plankton feeder but it may derive a significant portion of its food from bottom organisms. Zooplankton, terrestrial insects, and water mites compose a significant part of the Kokanee food at HVR. Kokanee as a result of their plankton diet and open water habitat may compete little even with other plankton feeding fishes (Scott-Crossman, 1973). Average volume of food in the stomachs appears to be highest in June and October.

Length-Weight and Scale-Age Analysis

Scales from Kokanee captured in 1976 were examined by these researchers, at the Biological Laboratory facilities at Carroll College. Also, Laney Hanzel, of the Montana Fish and Game Fishery Division at **Kalispell** Montana, calculated data for 1974 and 1976. John Clark, now with the Alaska Department of Fish and Game, Division of Commercial Fisheries, clarified and analysed data he collected from HVR in July 1974. All data was amassed and carefully, objectively scrutenized.

Kokanee scales and otolyths were examined for immature and mature fish respectively under a reflecting microscope (10x) and light microscope (45x). Hanzel examined the scales under oil immersion at 67 times the scale enlargement. Otolyth interpretation seemed more reliable than the scale reading due to the presence of

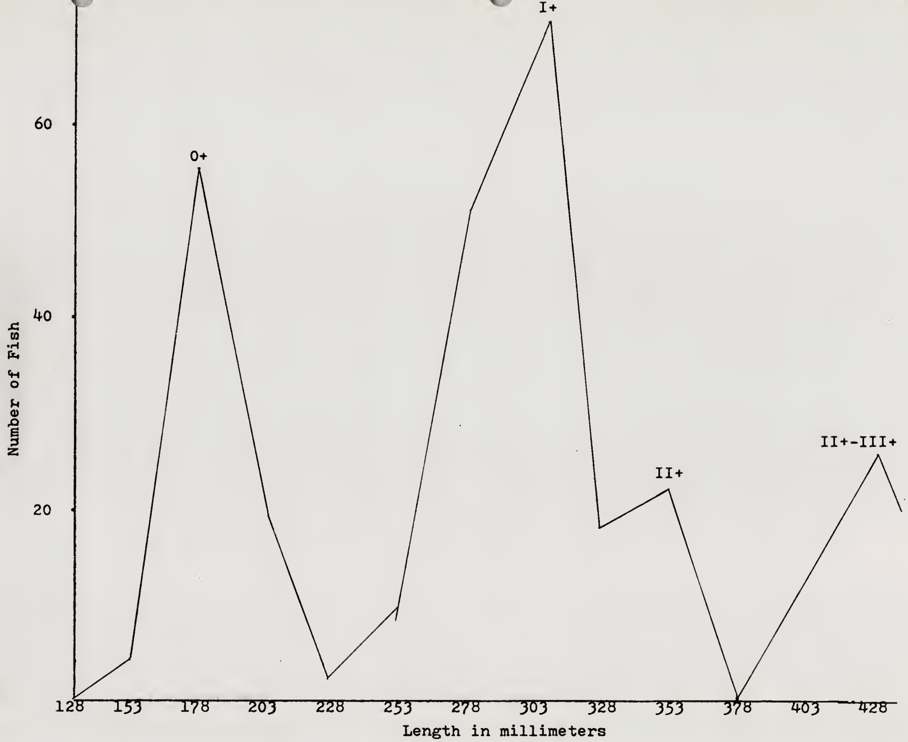


Figure 2
Age and length frequency for 1976 Kokanee at HVR.

many checks or groups of closely associated circuli rather than singular circuli; the result of slow growth as during winter.

By randomly calculating the age from the length frequency graph (Refer to Figure 2) we derived an overall relationship between fish age and its length and weight. The main objective of analysis was to correlate the average length-weight data with that conducted in the past years, and to determine the variability, if any, which has occurred.

As mentioned previously, Kokanee caught in 1969 were of record size as supported by the fact that the average weight (0^+, fish approaching age one, I+, fish approaching age two, II^+, III^+) was 800.07 grams, with a total average length of 431.10mm. Samples obtained in July of 1974 show a marked decrease in total average weight (217.46 grams) and length (286.20mm). This sampling marked the minimum, statistical position of the Kokanee in HVR. However, location of the nets in benthic and littoral areas of the lake moderated the catch so as to put the viability of this data in question. In other words, the location may not have been ideal or average Kokanee habitat.

Netting in October 1974 (Refer to Table 6) yielded Kokanee with a total average weight of 199.7 grams and total average length of 259.05 mm. Though this data is lower than the July data, information regarding II^+ year class was not available. In reference to Table 6, the I^+ and II^+- III^+ (Mature) of the October 1974 catch are

Table 6

Average weight and length analysis of Kokanee for years 1969, 1974, and 1976.

Year

Classification	Oct.- Nov.1969 (Clark-Traynor)	July 1974 (Clark)	Oct.-Nov. 1974 Fish & Game	October 1976
No. of fish	202	66	310	309
[a]Ave. wt. of 0+ class	___	___	44.6	50.95
Ave. wt. of I+ class	___	111	156.53	260.16
Ave. wt. of II+ class	___	292	___	429.17
*Ave. wt. of mature II+ and III+	___	279.4	397.91	697.82
Total ave. wt. of 0+, I+, II+, III+	800.07	217.46	199.7	359.51
[b]Ave. ln. of 0+ class	___	___	172.05	167.43
Ave. ln. of I+ class	___	224	235.38	284.61
Ave. ln. of II+ class	___	318	___	339.48
*Ave. ln. of mature II+ and III+	___	316.6	369.74	419.23
Total ave. ln. of 0+, I+, II+, III+	431.1	286.2	259.05	302.68

*All mature Kokanee were females.
[a]Weight measured in grams.
[b]Length measured in milimeters.
Note- This sign, ___, indicates insuffecent data available.

larger on the average than those of July 1974, which we could assume to be a more formidable indicator of the population health. October 1976 netting indicates that the general length-weight situation of the Kokanee in the HVR is on the upswing. With a total average weight (359.51 grams) and length (302.68mm) exceeding that of 1974, a significant population length-weight increase is indicated.

Coordinating the consistant data for July 1974, October 1974, and October of 1976 (Refer to Table 7), age I^+ and mature II^+- III^+ were combined, yielding a clearer view of the situation. Total average weight for the July 1974 catch was 195.20 grams, October 1974 at 277.22 grams, and October 1976 at 478.99 grams. Both the October 1974 and 1976 catches consisted of $2/3^+$ of the total Kokanee caught. A similar indication prevails with the average lengths; in July 1974 at 270.30 mm, October 1974 at 302.56 mm, and October 1976 at 351.92 mm.

To further emphasize that the Kokanee population at the HVR is on the rebound, mature Kokanee analysis was conducted for the years 1969, 1970, 1974, and 1976 (Refer to Table 8). Mature male and female Kokanee are classified as to their numbers respectively, percentage of total mature Kokanee count, and total average length-weight relation. Males and females had nearly identical weight-length coordination among each year catalogued; in 1976 males averaged 713.38 grams and females 710.30 grams, while in 1974, males averaged 410.21 grams and

Table 7

Analysis of length-weight frequencies for I+ and mature II+ - III+ in July and October 1974, & Oct. 1976.

Year	Ave. wt. of I+	Ave. wt. mature II+-III+	[a]Total ave. wt. of I+ and II+-III+	Ave. ln. of I+	Ave. ln. mature II+-III+	[b]Tot. Ave. ln. of I+ and II+-III+
July 1974	111	279.4	195.2	224	316.6	270.3
Percentage of total Kok count	34.84%	7.57%	42.41%			
October 1974	156.53	397.91	277.22	235.38	369.74	302.56
Percentage of total Kok count	30.68%	34.09%	64.77%			
October 1976	260.16	697.82	478.99	284.61	419.23	351.92
Percentage of total Kok count	48.89%	18.12%	67.00%			

[a]Weight measured in grams.
[b]Length measured in grams.

Table 8

Length-weight analysis of mature male and female Kokanee in the years 1969, 1970, 1974, and 1976 at HVR.

Date	Kokanee class.	No. of fish in class.	Percent of total mature Kok	Ave. Tot. **length	Ave. Total *weight
[a]1969-1970	Total mature male Kokanee caught	40	54.1%	506.4	1037.35
	Total mature female Kok caught	34	45.9%	508.9	1091.76
[b]1974	Total mature male Kokanee caught	17	42.2%	363.89	412.21
	Total mature female Kok caught	19	52.8%	344.21	357.53
[c]1976	Total mature male Kokanee caught	26	52.7%	442.11	713.38
	Total mature female Kok caught	29	47.3%	413.17	710.30

*Weight measured in grams.
**Length measured in millimeters.

[a]Study conducted by Clark and Traynor.

[b]Study conducted by Clark and the Montana Department of Fish and Game.

[c]Study conducted by O'Neill and Moen.

females 357.53 grams, compared with 1969-1970, with males at 1037.35 grams and females at 1091.76 grams. Therefore, it appears that the HVR offers a conducive fishery, that is not biased toward the sex of the species. Average data for mature Kokanee collected in 1974 represented a 274% decline compared to 1969. Similar Kokanee data for 1976 represented a 57.5% increase over 1974 and only a 149.5% reduction with respect to 1969.

Weight in fishes may be considered to be a function of the length. The length-weight or condition factor (K) was determined for HVR in 1974 and 1976. Values of K have been used widely by fishery investigators to express the condition, relative robustness, or "degree of well-being" of fishes (Lagler, 1952). On this basis, K has also been used as an adjunct to age and growth studies for indicating the suitability of an environment for a species, and to measure the effects of environmental improvement, including stocking (Cooper-Benson, 1951). The condition factor is determined using the general equation, $K = (10^5)W/L^3$, where W = weight in grams and L = length in centimeters.

For the 88 sampled Kokanee (October, 1974), the average condition factor for 5-inch fish and over was 33.27 with a confidence factor (standard deviation = 1.282) of 3167. Therefore, the degree of error expanded the range to 36.94 and 29.60 or approximately 80% reliability. For the 309 Kokanee sampled in October of 1976, the average

condition factor for 5-inch fish and over was 39.36 with a confidence factor (standard deviation = 1.282) of 4.80, at about 80% reliability. The degree of error expanded between 44.16 and 34.56. The minimum condition factor (34.56) for 1976, overlaps the minimum condition factor (36.94) for 1974, therefore no significant deviation between each of the two year classes can be resolved. Year class comparison per year would not produce valid approximation because group lengths under each study are not consistent. Ideally, considering the situation which exist at HVR, overlaping of average condition factor should not occur.

Population Density

Development of a viable fishery requires the inducement and maintenance of a fish population in relation to the waters area potential. What is the maximum number of fish which can be planted and which can attain maximum growth? After HVR was recognized as offering a viable Kokanee habitat, the Montana Fish and Game assumed the responsibility of stocking Kokanee in the reservoir (Refer to Figure 4). Fish fry (2-inches) were planted in the incurrent canal, ranging from 25,330 plants in 1971 to 135,540 in 1973. Since then, plants of Kokanee have averaged 41,435 in 1974, 1975, and 1976.

Fish fry are considered to be 0^+, and January 1, serves as the birthday for all fish. Therefore, fish fry planted in May 1971 (0^+) would be considered 0^+ until

January 1, 1972 when they would be I^+, and so on. Fish fry planted in May 1972 (0^+) would therefore be I^+ in 1973 and II^+ in 1974, the time of Clark's and the Montana Fish and Games analysis of HVR. Also, fish fry planted in 1971 (0^+) would be I^+ in 1972, II^+in 1973, and III^+ in 1974. Kokanee sampled in the 1974 catch are indicators of the fish which were planted in 1971, 1972, and 1973. Though it would not be rational to assume that all the fish (285,330) survived, the majority did.

Cause of the reduced Kokanee size was contended to be the result of high density or over-population (Frazier, 1974). With reference to Tables 5, 6, and 7 we indeed note a startling reduction in Kokanee in 1974, as compared with other years. What has resulted is over-population and forced intercompetition among the species. The population demand for food has exceeded the reservoirs supply, thereby as a result of the economics of the situation we recognize reduced Kokanee size.

This size reduction, resulting from over-population can also be correlated with the reduction in the water table for the years of 1972, 1973, and 1974 (Refer to Figure 3). Maximum drawdown of the reservoir water table occurred between the periods of June 1 - July 1 and July 15 - August 15. Irrigation demand has necessitated large water table reduction which as a result, reduces the productive fishery habitat of the reservoir (Refer to Figure 4). This reduction exposes a large quantity of

Figure 3

Planting data of fingerling Kokanee in the HVR, by the Montana Department of Fish and Game.

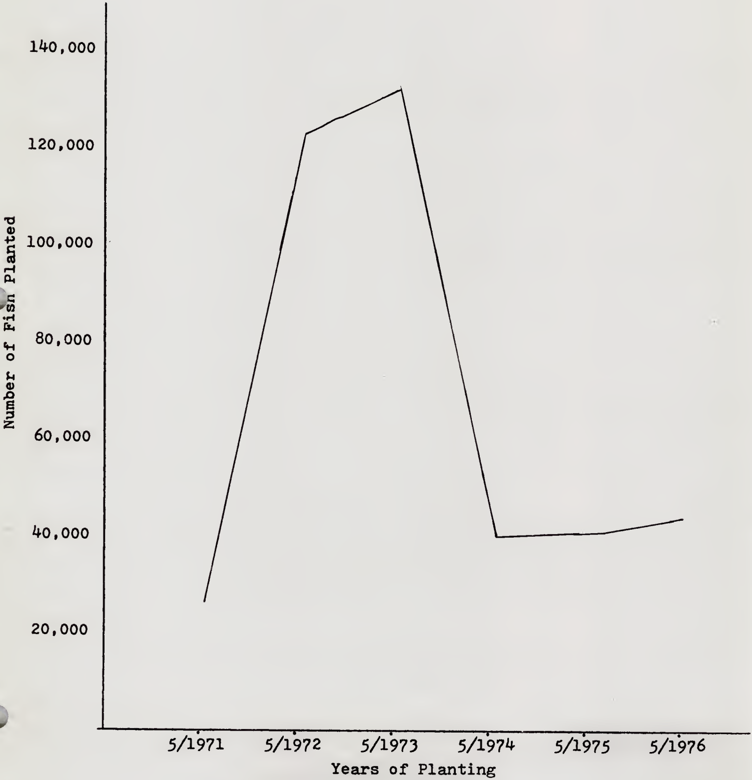
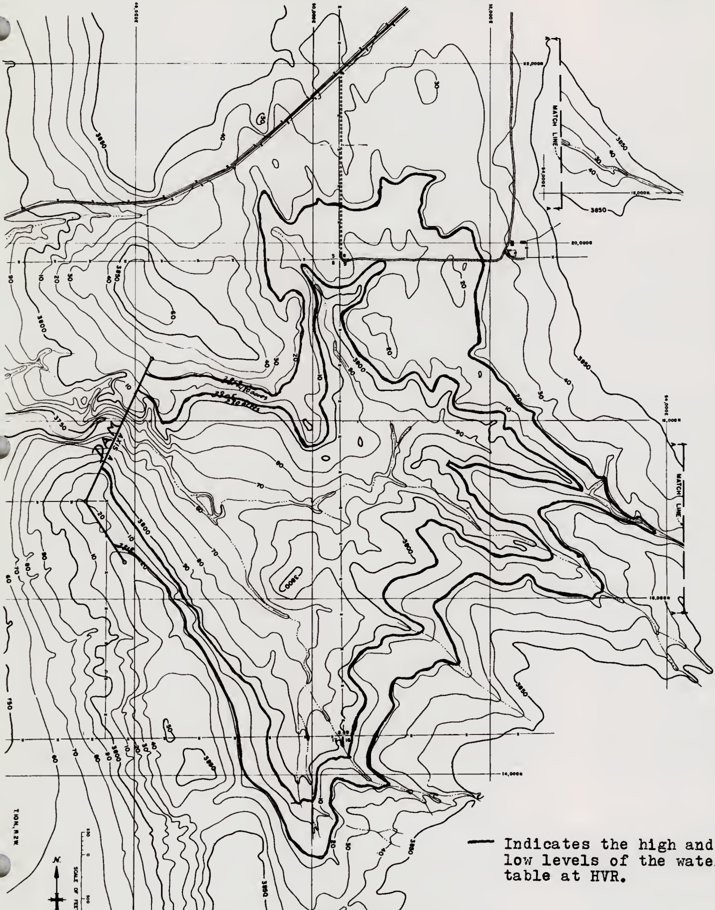


Figure 4

Surface Area Map of HVR.



— Indicates the high and low levels of the water table at HVR.

shoreline, and reduces the reservoirs capacity to provide cool water in summer months. As mentioned previously, warming of the water expands the depth of the epilemnion, lowers and decreases the depth and volume of the thermocline and overall, limiting the area of conducive Kokanee habitat at the HVR. Therefore the majority of Kokanee in the reservoir will be congregated in the area of reservoir depth that can be tolerated.

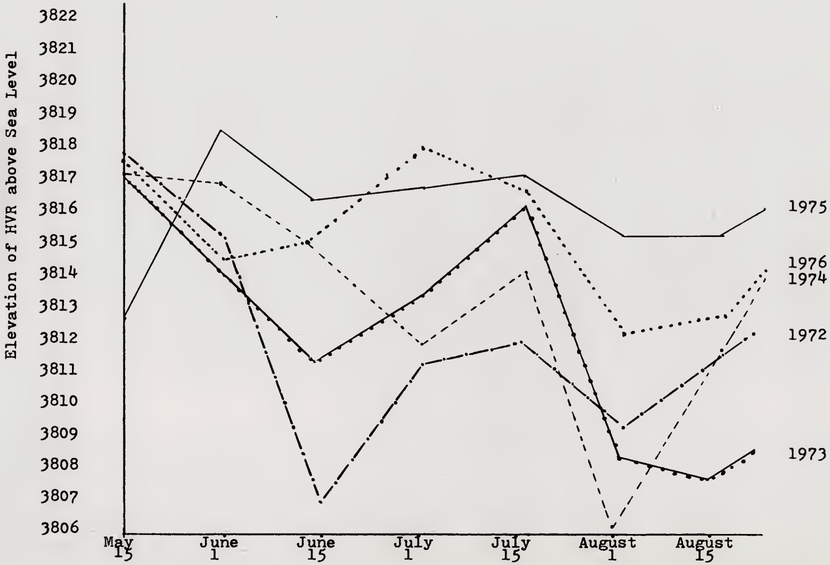
Kokanee planted in May of 1973 (0^+) were III^+, 1974 (0^+) were II^+, and 1975 (0^+) were I^+ in the October 1976 sampling (May 1976 (0^+) were also caught). Kokanee (III^+) were part of the 135,540 planted in 1973, II^+ and I^+ were part of the reduced Kokanee plants which averaged 40,440. Total planting analysis for these three years (1973, 1974, 1975) equalled 216,420 or 75.8% of the 1971, 1972, 1973 totals. Planting in 1974, 1975, 1976 totaled 124,300 or 43.5% of the 1971, 1972, 1973 plantings; a significant decrease.

Notice that in 1975 and 1976 the water drawdown was very moderate as compared with the previous three years; this correlated with reduced planting (decreased population density) should result in increased fish size in our 1976 sampling. Indeed there has been an increase in size for the 1976 age groups (Refer to Figure %) of the Kokanee species in the HVR.

Removal of a predatory fish in Cultus Lake, B.C. (Foerster-Ricker, 1941) presented as example of over-population, by a 3 fold increase in the survival of young

Figure 5

Comparison of water levels in HVR for years 1972-1976.
*Filling to capacity occurs between April 1-May 15.



sockeye salmon. Because of the increased survival, the average weight of the individual fish was nearly reduced to half. This indicates that the over population of a warm water species such as Kokanee, would result in reduced growth.

Sucker

The white sucker (Catastomus commersoni) is found in waters with cold and warm temperatures, high and low turbidity, and reaches maximum abundance in man-made impoundments (Brown, 1971). Spawning occurs in the spring, usually from early May to June (Scott-Crossman, 1973), and individuals may spawn from 1-4 times. Suckers are usually fish of lakes or warm, shallow bays.

The fry at 12mm length begin feeding near the surface on plankton and other small invertebrates. At 16-18mm, the period when the mouth moves from terminal to ventral, there is a shift to bottom feeding, where they feed on aquatic invertebrates, diatoms, algae, and debris (Brown, 1971). As bottom feeders they do not constitute serious competition for other browsing, shallow water fish (Scott-Crossman, 1973).

Sucker Competition with Kokanee

Previous interpretation of the reduced size of Kokanee in the HVR was relegated to its direct interactive competition with the reservoir white sucker population. However, these studies may have been biased in their

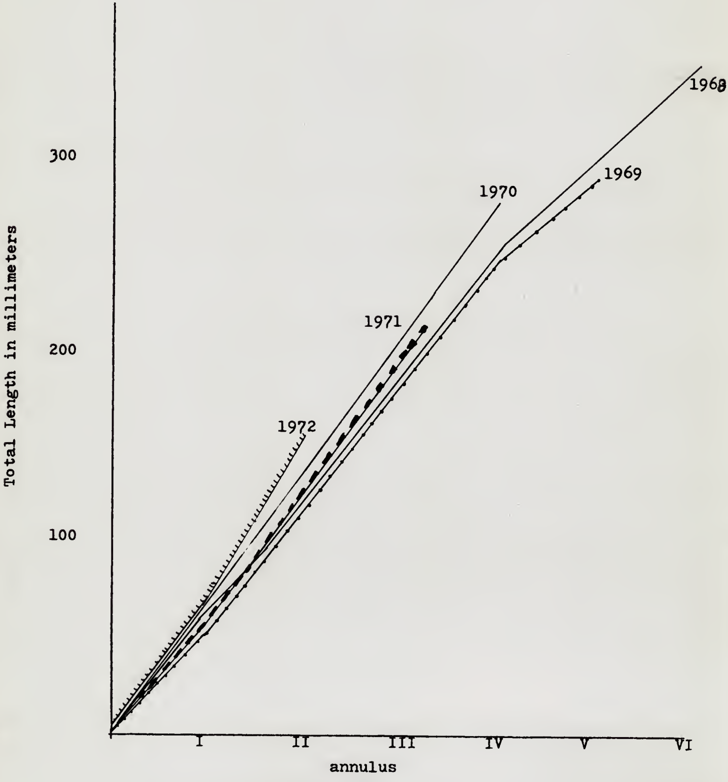
selection methods; placing nets in the shallow, littoral, and benthic zones of the reservoir (Clark-Traynor, 1971). Also nets were placed in these areas during the daytime (Clark, 1974) when temperatures would not stimulate Kokanee migration into these areas.

Sucker analysis was conducted by Rauch (1974), who captured the majority of the 223 suckers in the benthic zone. Age, length-weight calculations of his subsampled group (79) produced weighted mean total lengths at each annulus, providing an index of past growth averages. His results do not support any evidence of a high density white sucker population, but indicate a remarkably stable population (Rauch, 1974). As compared to other studies the growth rates were not high, in that it almost duplicates that of the Missouri River, Montana (Kathrein, 1950). In fact, the overall coefficient of condition (K-factor) of 1.01 (range .84 to 1.19) for HVR white suckers is considered poor by Minnesota standards (Minnesota study conducted by Eddy and Carlander, 1940) as reported by Rauch (1974). Stability can be seen in the growth of succeeding year classes (Refer to Figure 6), indicating that a constant environment of adequate food supplies and favorable conditions occur (Rauch, 1974). This seems to indicate the idea of a large white sucker population as inaccurate.

Intensive netting of the longnose sucker (Catostomus catostomus) at Pyramid Lake, Alberta was initiated in order to improve the rainbow trout angling. They succeeded

*Figure 6

Yearly growth rates of white suckers from HVR July 1974.
*From Rauch, 1974.



in reducing the average size of the sucker taken in gill nets from 5.4 to 1.6 ounces over a 5 year period (Rawson-Elsey, 1950). Although the number of large suckers was reduced, the number of young suckers increased. The rainbow did not show any increase during this time or 3 years after. Because of the similar food habits of these species, theoretically there should have been a size increase. Again the phenomenon of a high density population seems exhibited as a controlling factor.

Active feeding of the white sucker is usually restricted to near sunrise and sunset when they move to shallow water. Data concerning the sucker catch per gill nets set, and the length-weight relationship has been tabulated for the years of study at HVR (Refer to Table 8).

Conclusion

Our research at the HVR indicates that many factors may influence the growth of Kokanee. Water temperature, oxygen concentration, water conductivity, climatic factors, reservoir water table fluctuations, inter-competition with suckers, and intra-competition resulting from a high density population all interact to produce a unique ecosystem. We have not committed ourselves to say any one or two systems maintain control, but have relayed the degree which we feel each contribute.

There exist in nature a harmony and balance among the variable species. When the weight falls toward one

Table 9

Maximum and minimum lengths and weights of white suckers, gill netted in HVR in 1965, 1968, 1969, 1970, 1974, and 1976.

Date	Type of Set	No. of set	Tot. no. of sucker	Ave. no. Suckers / net	Max. ln.	Min. ln.	Max. wt.	Min. wt.
6/15/65	Bottom-night	1	47	47	17.2	6.7	2.16	0.12
6/25/68	"	2	266	133	*	*	*	*
6/16/69	"	1	38	38	16.5	6.4	1.6	0.10
6/16/69	Surface-night	1	117	117	18.2	6.5	2.5	0.10
10/69-9/70	Bottom-night	5	*	*	*	*	*	*
10/69-9/70	Surface-night	5	*	*	*	*	*	*
1/74-3/74	Bottom-night	2	80	40	*	*	*	*
7/8/74-7/22/74	Surface-night	15	982	65	*	*	*	*
**7/74	Surface-night Bottom-night Bottom-day Surface-day	8	223	28	17	7.0	*	*
***10/16/74	Surface-night	6	3	0.5	*	*	*	*
	Surface-day	1	3	3	13.2	11.2	0.76	0.49
	Bottom-day	1	9	9	16.8	8.8	1.79	0.19
10/18/76	Surface-night	6	133	22.2	15.7	7.5	*	*

*Insufficent amount of information available.
**Richard E. Rauch report.
***Surface and bottom day nets placed for 3 hours; all others averaged between 16-24 hours.

Note- Sucker count includes white sucker (Catostomus commersoni), and the longnose sucker (Catostomus catostomus).

end or the other, a feedback response signals recourse for correction. In the case of the HVR, the ecosystem that is peculiar for this reservoir could not balance the large Kokanee population. As a result, the situation had been modified to the extent of reduced Kokanee size.

Future Predictions

As indicated in the October 1976 catch, the carp (*Cyprinus carpio*) species captured, presents a problem at the HVR. The carp is an omnivorous feeder and vegetation and detritus make up the bulk of its diet, but almost all available aquatic organisms of suitable size are eaten (Brown, 1971). They prefer moderately warm, shallow water where aquatic vegetation is plentiful, and generally live less than 10 years, though records indicate up to 50 years of age. Whether carp will have more of an effect on the sucker population, because of its desired habitat, or on the Kokanee population can only be hypothesized.

Considering that there is a large population of I^+ and II^+ Kokanee moving toward maturity and therefore greater size (Refer to Figure 7), fisherman success with respect to large Kokanee hooked and number hooked should be excellent for 1977 and 1978. However, climatical factors may be significant force in determining the frequency of future success. Weather forecasts indicate that the summer of 1977 will be dry; thus coupled with low snowpack in the higher elevations

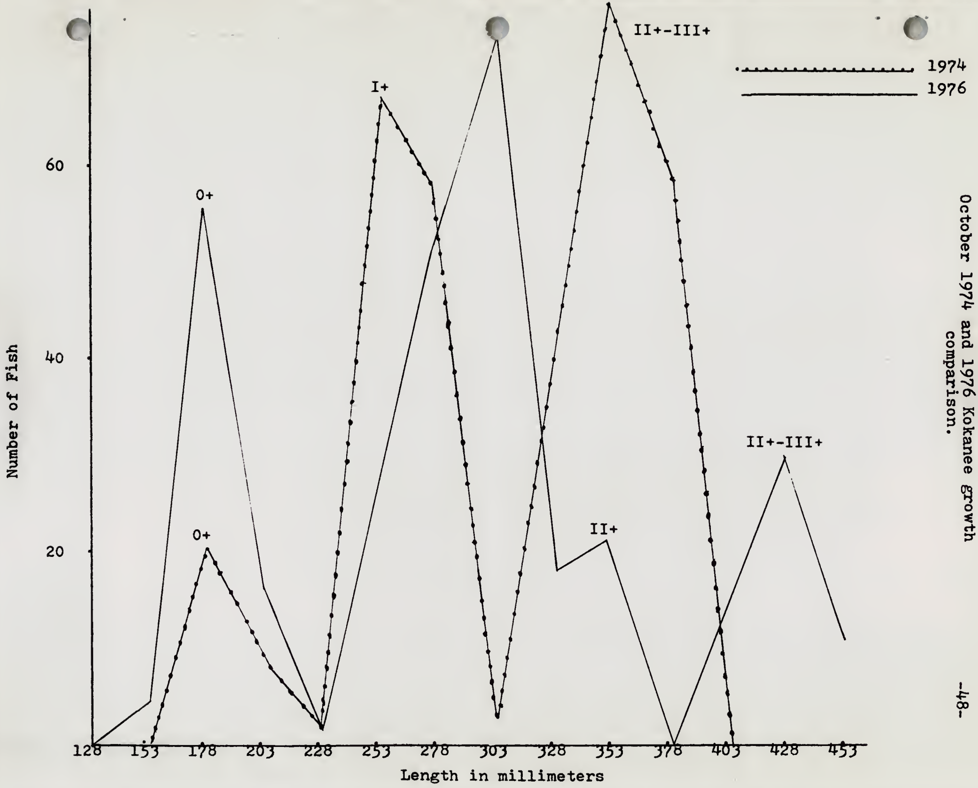


Figure 7
October 1974 and 1976 Kokanee growth comparison.

and increased irrigation demand its effect on Kokanee may be detrimental. Though predictions at this time may be inconsistant and inaccurate with what may occur, the possibility does exist.

In regards to the Kokanee plants at the HVR in May, 1977 we suggest that plants be further reduced to 25,000-30,000 fingerlings to accomodate for the possible increased irrigation requirements. This should insure continued increased growth within the Kokanee population. However, the possibility of reaching the plateau of producing again, large numbers of record size Kokanee does appear possible though not probable.

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